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Research Paper Review

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The Clinical Value of Assessing Lumbar Posteroanterior Segmental Stiffness: A narrative review of instrumental methods

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ABSTRACT

INTRODUCTION: *Abnormal spinal segmental motion/stiffness is purported to be a cause, or an effect of, low back pain. Therefore, the assessment of posteroanterior segmental spinal stiffness is a common practice in clinical and research settings. In clinical settings, manipulative practitioners routinely assess spinal stiffness manually to guide clinical decision-making. Unfortunately, the reliability of manual segmental spinal stiffness assessment is poor. As a result, various spinal stiffness-testing devices have been developed to improve the reliability and accuracy of spinal stiffness measures. Although previous critical and systematic reviews have summarized the evidence regarding the reliability and confounding factors of manual and/or instrumented spinal stiffness measurements, no available review has summarized the principles of various spinal stiffness measurement methods nor pragmatic recommendations to optimize these measurements. Importantly, although posteroanterior segmental spinal stiffness is hypothesized to be related closely to low back pain or clinical outcomes after treatments, no review has been conducted to summarize evidence related to these premises and to discuss factors that can confound these relations.*

METHODS*: The authors performed a literature search for relevant research using PubMed from its inception to March 2016. Articles were included if they reported the reliability of manual segmental spinal stiffness assessment (MSSA) or instrumented spinal stiffness testing, or the associations between segmental spinal stiffness and LBP. Articles were excluded if they reported spinal stiffness measurements of animals or nonbiological materials.*

CONCLUSION*: The use of instrument-assisted postero-anterior spinal stiffness measurement technology in clinical and research settings has shown that a reduction in PA segmental spinal stiffness is associated with alleviation of LBP in some populations, which is certainly promising. Some of the variance*

of this relationship is mediated by demographic, psychological and neuromuscular factors, which may need to be accounted for and controlled in research and clinical settings.

ANALYSIS

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Background Information

Low back pain (LBP) is a common affliction that is associated with tremendous work-related and personal socioeconomic costs. Approximately 90% of LBP cases are thought to be mechanical in origin (1). Because the exact mechanical source of LBP is often unclear, clinicians may use their physical examination findings to classify patients into presumed homogenous LBP subgroups (2, 3), with the goal of optimizing treatment outcomes (4). To this end, manual assessment of segmental, posteroanterior (PA) stiffness is a commonly employed physical examination procedure. Unfortunately, this procedure (also referred to as manual segmental spinal stiffness assessment, or 'MSSA') has extremely low intra- and interrater reliability. To eliminate this subjectivity, various instrumented spinal stiffness-testing devices with superior reliability have been invented, but are (currently) only available for clinical research purposes. In this review, the authors discussed the evidence behind both manual and instrumented segmental lumbar stiffness assessments. They also summarized the evidence linking LBP and PA spinal stiffness, as quantified by instrumented spinal stiffness-testing devices.

Summary:

Clinicians typically use manual assessment (MSSA) to clinically evaluate segmental spinal stiffness, and/or to reproduce the patient's pain. This assessment is performed by manually applying a PA force (by pisiform or thumb tip contacts) to a prone patient's spine. A perception of high resistance to PA forces denotes high spinal stiffness (hypomobility), while a perception of low resistance to spinal motion denotes low spinal stiffness (hypermobility) (5). Unfortunately, the intra- and interrater reliability of MSSA are suboptimal (average kappa values 0.35 [6] and 0.17 [7], respectively – both considered poor). Several factors, including examiner-, patient- and environmental-factors negatively affect the reliability of MSSA, which are detailed below.

Examiner-Related Factors Affecting Reliability:

- Vision can negatively affect the examiner's perception of stiffness by raising the magnitude of perceived stiffness. To counteract this, clinicians and researchers must fix their gaze during MSSA to minimize inconsistency.

- The manual technique, frequency, speed and force of spinal loading affect the viscoelastic properties of spinal tissues. Using a thumb-tip technique to measure MSSA consistently yields lower perceived stiffness magnitude compared to using a pisiform contact. Standardization of hand placement and use of a metronome to standardize frequency/speed of loading are thus required in clinical settings to (theoretically) improve reliability. This also implies that one should utilize the same techniques over time when clinically assessing patients.

- Some clinicians inform their clinical decisions about spinal stiffness by palpating overall displacement of examined segments, while others perceive spinal stiffness based on the 'end-feel' of PA motion. This lack of quality standard unfortunately decreases the clinical reliability of MSSA.

- Protocols to match the feeling of spinal stiffness with reference materials of known stiffness have been created, but have only been tested in non-clinical populations. Use of a 3-point grading scale (hypermobile, normal, hypomobile) has also been advocated, but has shown variable reliability, depending on the study. Because intra-rater reliability is higher than inter-rater reliability, it is recommended that the same clinician examine spinal stiffness in every patient.

Patient-Related Factors Affecting Reliability

The patient's trunk muscle tone and respiratory cycle can influence measurement of PA lumbar stiffness. Clinicians must instruct patients to volitionally relax their trunk muscles and to hold their breath at functional residual capacity during these assessments. Certain non-modifiable factors, such as adiposity and gender, can additionally affect the perception of PA stiffness.

Environmental-Related Factors Affecting Reliability

The measurement surface (ex. rigid surface vs. padded surface) can affect average instrument-assisted spinal stiffness measurements, which requires testing surfaces to be standardized.

Unfortunately, while these recommendations have been made to rectify potential issues affecting reliability of spinal stiffness measurement, the utility of these recommendations remains unclear.

Spinal Stiffness Analysis Via Instrumented Methods in Research Settings:

The various force and displacement properties of spinal segments are objectively measured using instrumented PA stiffness measuring devices. This information is used to create force-displacement curves, which enables calculation of segmental spinal stiffness. Unfortunately, the process used to calculate spinal stiffness is not consistent among laboratories, which precludes direct comparison among their studies.

The test-retest reliability of instrumented lumbar stiffness measurements in human subjects is high (Intraclass Correlation Coefficients [ICC] of 0.79-0.99, depending on the device). To mitigate patient- and environment-related factors that affect reliability of instrumented MSSA, the following recommendations have been made:

1. Voluntary trunk muscle activity is minimal;
2. Lung volume is at functional residual capacity;
3. Ribcage and pelvis are not constrained;
4. The patient's posture is neutral; and
5. Standardization of the testing surface (soft vs hard) and loading parameters (i.e. frequency, speed, force).

Individual characteristics, such as gender, adiposity and degree of disc degeneration should also be considered, as these factors influence PA stiffness measurement.

Relation Between Segmental Spinal Stiffness and LBP:

Mechanical LBP is thought to be associated with aberrant/impaired intervertebral joint motion or function. Clinicians routinely use MSSA to classify patients with LBP into subgroups based on spinal mobility (i.e. hypermobile, normal, hypomobile). While these categories potentially dictate treatment and reflect the heterogeneity of LBP, they may also be artifacts of unreliable MSSA and/or natural variations of the human body. The following discusses the use of highly reliable instrumented measurement of PA segmental spinal stiffness in patients with LBP in research settings. Clinical MSSA was excluded from this review because of its poor reliability.

LBP and increased spinal stiffness have been found to be cross-sectionally related in both asymptomatic and symptomatic cohorts (8, 9). However, these studies failed to estimate the correlation between absolute segmental spinal stiffness values and the corresponding LBP intensity.

Other laboratories have shown no significant difference in average PA segmental lumbar stiffness values between symptomatic and asymptomatic individuals (10) and have failed to demonstrate significant bivariate correlation between PA lumbar stiffness and LBP severity/chronicity before SMT treatment (11). Unfortunately, this latter finding may have

been affected by inconsistent manual loading parameters during the mechanically-assisted spinal stiffness tests (12).

Does segmental spinal stiffness change as LBP subsides?

Collectively, the evidence shows that lumbar PA stiffness generally decreases as LBP subsides in some, but not all, individuals suffering from LBP (13-16). The lack of consistency is likely secondary to the heterogeneity, and non-specificity of LBP symptoms.

Is it necessary to have a baseline assessment of spinal stiffness to predict LBP outcomes?

Clinical prediction rules (CPRs) to screen for positive responders to spinal manipulation in relation to segmental hypomobility, and spinal stabilization exercise in relation to segmental hypermobility have been created. Utilization of the CPRs has been demonstrated to improve efficacy of LBP treatment. However, these CPRs have been heavily criticized by many because of the poor reliability of MSSA. *EDITOR'S NOTE: this is an area where further research on spinal stiffness measurement could really impact patient care in terms of applying appropriate treatment techniques to patients more likely to positively respond.*

Subsequently, studies have attempted to predict clinical outcomes in patients with LBP by measuring baseline spinal stiffness using more reliable instrumented spinal stiffness-testing devices. Collectively, these studies showed that some patients with LBP with lower baseline segmental spinal stiffness values may benefit from spinal manipulation. However, this conclusion requires further study on a larger scale.

While the evidence suggests that instrumented PA segmental lumbar stiffness is cross-sectionally and temporally related to LBP, and may predict LBP outcomes post-SMT, the relationship between PA segmental lumbar stiffness and LBP may be confounded by multiple factors. For example, older age and male gender are associated with greater spinal stiffness, while female gender and higher adiposity are associated with lower PA spinal stiffness. Neuromuscular factors such as heightened muscle activity (i.e. spasm, tone), and/or abdominal muscle weakness/inhibition are also theorized to modulate spinal stiffness. Psychological factors such as anger, fear, anxiety, depression and catastrophizing can increase superficial paraspinal muscle activity in patients with chronic low back pain and are independently associated with pain ratings via altered subcortical and/or cortical pain processing. Unfortunately, no studies have been conducted to quantify how much these psychological factors may modulate the relationship between PA stiffness and LBP.

CLINICAL APPLICATION & CONCLUSIONS

The authors of this review synthesized the best and most current literature and provided pragmatic recommendations for improving the reliability/accuracy of manual segmental spinal stiffness assessment (MSSA). Because of MSSA's low reliability, they advocate for

the use of instrument-assisted postero-anterior spinal stiffness measurement technology in clinical and research settings. The use of such technology has shown that a reduction in PA segmental spinal stiffness is associated with alleviation of LBP in some populations, which is certainly promising. The authors also stated that some of the variance of this relationship is mediated by demographic, psychological and neuromuscular factors, which may need to be accounted for and controlled in research and clinical settings. Future research should endeavor to establish normative lumbar stiffness values in asymptomatic individuals, to enable recognition of aberrant spinal stiffness values in symptomatic patients.

STUDY METHODS

The authors performed a literature search for relevant research using PubMed from its inception to March 2016. Articles were included if they reported the reliability of manual segmental spinal stiffness assessment (MSSA) or instrumented spinal stiffness testing, or the associations between segmental spinal stiffness and LBP. Articles were excluded if they reported spinal stiffness measurements of animals or nonbiological materials. Sixty articles were included for review.

STUDY STRENGTHS/WEAKNESSES

The authors did their best to provide advice on how to improve the reliability of MSSA for the average clinician that does not have access to instrumented measurement technology.

The authors did discuss some of the literature around how different sensory inputs (ex. sound) can affect the patient's perception of stiffness (see Stanton et al. 2017 [17]). They also did not discuss how the relationship between the flexion/relaxation phenomenon, PA spinal stiffness, LBP and SMT efficacy may be altered specifically in chronic LBP populations (Xia et al 2017 – [18]). Lastly, they also do not discuss whether the reliability of clinical MSSA improves if pain is reproduced during the physical examination procedure.

Commentary from Dr. Greg Kawchuk

I wanted to take this chance to not comment on this paper, but to point out some developments that have happened along the way that make this paper even more relevant than when it was published.

Although we see an increase in the attention paid to the psycho aspect of the biopsychosocial model with respect to back pain (and rightfully so), we are experiencing a bit of a new age for spine stiffness as well. While the idea that tissues in trouble change

their stiffness is as old as clinical interventions themselves, new technologies are showing just how interesting this measure is becoming to clinical practice.

For example, we are beginning to gain a better understanding of how the biomechanical measure of stiffness relates to the subjective experience of back stiffness. In fact, it appears they do not relate at all – these two concepts represent different domains in the same way that measuring how many flights of stairs a patient can climb is unlikely to be related to the flights they report they could climb. While one measure is biomechanical, the other takes on many different inputs including the effect of our surroundings and our experiences. Tash Stanton, a former Master's student from our lab who is now working with Lorimer Moseley, has recently shown that a person's impression of their back stiffness can be influenced by sounds that are playing to them while their biomechanical stiffness remains unchanged. This creates a powerful opportunity for researchers and clinicians alike – to have a variable (stiffness) that not only changes in those who report an improvement in disability following SMT, but a variable that can also be potentially influenced by the experience we provide for our patients.

This is perhaps the most important message I have in this editorial – it is old school to think of the mechanisms of treatment as being neurological or biomechanical or cognitive. We are in an age where we now have interventions that are touching on all these elements while understanding how those elements work together. Just like we learned in school, it really is about treating the whole patient.

Dr. Greg Kawchuk BSc, DC, MSc, PhD is a professor in the Faculty of Rehabilitation Medicine at the University of Alberta. Greg is a CMCC graduate (1990) who practiced chiropractic for 15 years in multidisciplinary settings before becoming a full-time researcher. He was the recipient of the first chiropractic research chair in Canada and in 2004, was recruited to the University of Alberta as the Canada Research Chair in Spinal Function. Dr. Kawchuk's research interests are focused on back pain and spine function. His work spans basic science, clinical trials and recently, healthcare reform. A major component of his research is developing novel technologies to measure spinal function then employing those technologies to evaluate clinical interventions. Competitive awards from major provincial, national and international funding agencies support Dr Kawchuk's work and include AIHS, AITF, CIHR, NSERC, NIH. To date, his work has resulted in over 100 papers, the most recent of which have been published in The Spine Journal, Pain, Scientific Reports and PLOS One. Dr. Kawchuk is currently the Research Council Chair of the World Federation of Chiropractic.

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